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ELECTRONIC TRANSFER BETWEEN DNA OR BETWEEN RNA OF SLIGHTLY DIFFERENT CHEMICAL STRUCTURES

/Following is a translation of an article by Mme Andree Goudot, presented at the 8 April 1963 meeting of the French Academy of Sciences and published in the French-language periodical Comptes rendus de l'Academie des Sciences (Reports of the Academy of Sciences), Vol 256, 1963, pages 3528-3531, under the subject heading of Electronic Biochemistry./

The addition of a halogen at peak 5 of a pyrimidine turns the RNA so modified into a "donor" on a DNA or a normal RNA. That is why FU and FO are able to prevent the division in half of the DNA. The addition of CH_3 on the cytosine turns the DNA of the T_2 phage into an "acceptor" with regard to the DNA of E. coli. This is what may cause the formation of the DNA of the phage at the expense of the DNA of the bacterium.

In two earlier articles (A. Goudot, Comptes rendus, Vol 255, 1962, p 3420; Vol 256, 1963, p 1776. In these two articles guanidine was written erroneously instead of guanine, while Fig. II indicates guanine correctly), it was shown, with the aid of the calculation of the energy levels of the mobile electrons, that under certain conditions there is a passing band (Brillouin zone) in polynucleotides. This conduction band allows resonance along the axis of the DNA or RNA molecule through transfer of a pair of electrons between the molecules of the successive purine-pyrimidine planes. This resonance favors copolymerization.

In addition, a transfer of electrons may be established between purine-pyrimidine planes of two different DNA or

of an adjacent DNA and RNA. For this to occur, the highest level occupied by the "donor" has to be just above the lowest free level of the "acceptor". However, no conduction band is formed there, for the transferred electrons generally remain on the purine-pyrimidine "acceptor" molecule plane instead of resonating on all the purine-pyrimidine planes of the molecule to which this plane belongs. This pair of given electrons may, nevertheless, serve as a π bond between the purine-pyrimidine "donor" and "acceptor" planes.

A redistribution of the charges on the atoms of the "donor" and of the "acceptor" ensues from this electronic transfer.

The "donor", as a result of the loss of two electrons, may, according to the particularly "discharged" atoms either (1) divide in two if they are the bonding atoms between purine and pyrimide [sic; should read "pyrimidine"] or (2) they divide in the vertical direction if the N atoms are the ones that join the pyramidine and the purine to the sugars.

Comment. In order for these interactions to be possible in vivo, it would be necessary for the nucleotides to be deprived previously of the proteinic component that protects them so that there is no screen between the two DNA or the DNA and the RNA that must interact.

Intra-RNA Transfer. Cancerous cells utilize uracil in a preferential manner. This may be due to the fact that since RNA is an "acceptor" with regard to DNA it obliges the DNA, of which two atoms have particularly become positive, to split more rapidly than normally. Whence a more rapid formation of RNA, following an abnormal, accelerated metabolism.

On the other hand, by substituting the uracil with such derivitives as 5-fluoro-uracil (FU) or 5-fluor-orotic acid (FO), it is possible to inhibit the proliferation of the cells of certain cancerous tumors (G. Deysson and R. Truhaut, Bull. Soc. Chim. Biol., 44, 1962, p 613). A study of the electronic structure of A-FU has already been made (Goudot, loc. cit.). It shows that RNA containing the halogen atom is a "donor" with regard to normal DNA, instead of being an "acceptor" like normal RNA. Therefore, it does not cause cleavage of DNA.

5-fluor-orotic acid is less active as a carcinostat than 5-fluoro-uracil, but it is interesting, nevertheless,

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to know whether it acts in the same way, from the electronic point of view.

The calculation of the energy levels of the free electrons was made on an RNA containing adenine-5-fluor-orotic acid (A-FO) alternating with the guanine-cytosine planes.

Adenine-5-Fluor-Orotic Acid

Occupied levels: 6.1509, 3.8223, 3.6790, 3.6487, 3.4339, 2.8760, 2.8390, 2.4668, 2.3101, 1.6193, 1.2407.

Lowest free level: 0.9704.

Guanine-Cytosine

Highest occupied level: 1.3209.

Lowest free level: 1.1785.

There is no conduction band in the RNA formed by FO and GC alternating. What are the possible relationships between RNA_{FO} and normal DNA?

Adenine-Thymine in Normal DNA

Highest occupied level: 1.6295.

Lowest free level: 1.2410.

The highest occupied level (1.2407) of the A-FO is practically the same as the lowest free level (1.2410) of the AT. The normal DNA has become an "acceptor" with regard to the RNA_{FO} instead of being a "donor" as it is with respect to the normal RNA. In the presence of RNA_{FO}, then, the normal DNA no longer loses the pair of electrons that entails its induced cleavage, as the normal RNA is able to do. Therefore, RNA_{FO} does not cause mitosis and its carcinostatic effect is probably due to that. Nevertheless, it is less "donor" than FU, therefore, without doubt, less active for that reason.

But without penetrating within the nucleus as has just been assumed, is there an interaction between RNA_{FO} and normal RNA in the cytoplasm?

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Adenine-Uracil in Normal RNA

Highest occupied level: 1.7709.

Lowest free level: 1.2534.

It is seen, according to these energy levels, that A-FO has its highest occupied level (1.2407) above the lowest free level (1.2534) of the adenine-uracil of normal RNA; therefore, FO is a "donor" with regard to normal RNA. Normal RNA receives the pair of electrons in the 1.2534 free level (of AU), which then becomes its highest occupied level (HOL). Its lowest free level (LFL), then, is 0.9853 too high in order to receive a pair of electrons from the HOL (1.6285) of AT or from the HOL (1.3209) of GC. The "supercharged" RNA can no longer be an acceptor of a pair of electrons from the normal DNA, therefore, it can no longer produce cleavage of this DNA.

Intra-DNA Transfer. Certain bacteriophages, such as T_2, that infect E. coli, do not have RNA and have a DNA in which 5-methylcytosine replaces the cytosine (F. Lepine, Problemes d'organisation et de fonctions chez les bacteries et les virus [Problems of Organization and Functions in Bacteria and Viruses], Paris: Masson, 1958). Now, this DNA with methylcytosine (CM) imposes its structure in the metabolism of the infected bacterium.

It is not possible, in the free state in the nucleus, for the electronic interaction between $DNA_{bacteria}$ and DNA_{phage} to be responsible for this fact, inasmuch as, normally, the DNA is protected by histone. Now, in order for an electronic transfer to occur theoretically between DNA_{phage} and $DNA_{bacterium}$, it is necessary for the two DNA to be very close to each other and for the pyrine-pyrimidine planes of one to be in the prolongation of or to be parallel to the planes of the other. It is possible for the requisite conditions to be fulfilled. In fact, the $DNA_{prophage}$ is incorporated in a determined place in the bacterium's chromosome (P. Nicolle, Rev. Pathol. gen. et Physiol. Clin., No 692, 1957, pp 1501-1516). This place is without doubt normally reserved for the bacterium's DNA. Moreover, it is known (R. C. Williams, Rev. Mod. Phys., 31, 1959, p 234) that when the DNA of the phage polymerizes it contains certain fragments of DNA from the host bacterium. It may, therefore, be assumed that $DNA_{bacterium}$ and $DNA_{prophage}$ must be adjacent to each other in the chromosome. It may also be assumed that when the $DNA_{bacterium}$ has been

fragmented, each purine-pyrimidine complex then has all its mobile electrons resonating in a plane perpendicular to the plane of the atoms located in the purine-pyrimidine plane. Due to this fact, the energy levels are normally occupied.

We then have:

	DNA (bacterium) AT	DNA (bacterium) GC	DNA (prophage) GMC
Highest occupied level	1.2410	1.1785	1.3217
Lowest free level	1.2239	0.9971	1.3026

It is evident that the $DNA_{bacterium}$ is able to "give" a pair of electrons to the $DNA_{prophage}$ by means of transfer from the HOL (1.2410) of AT on to LFL (1.3026) of GMC.

This transfer can cause the dissociation of the $DNA_{bacterium}$ and the pair of electrons "given" on a level of the $DNA_{prophage}$ may serve as a π bond between AT coming from the bacterium and G-MC of the phage.

Discussion. The purine-pyrimidine AT and GC planes alternate, in the DNA of the bacterium, according to a sequence such as $[(A + T)/(G + C)] = 1$. A similar sequence must occur: $[(A + T)/(G + MC)] = 1$ in order for the DNA of the prophage (after dissociation of the phage) to be able to be incorporated in the same "place" in the chromosome as the DNA of the bacterium. Now, according to the results obtained by calculation, it seems that AT coming from the DNA of the bacterium must be joined to the G-MC of the DNA of the prophage. Since the DNA of the prophage contained as many AT planes as GMC planes, the DNA of the phage that is formed with the aid of the DNA of the prophage and of the AT coming from the DNA of the bacterium should yield a sequence in which two purine-pyrimidine planes of the prophage enter for one of the DNA of the host bacterium. Then, the sequence of the DNA_{phage} is:

$$[(A + T)/(G + MC)] = 2.$$

The sequence in the $DNA_{prophage}$ is unknown experimentally. But the sequence that was found for the DNA_{phage} agrees with the numbers given for the DNA that were synthesized enzymatically (A. Kornberg, Rev. Mod. Phys., 31, 1959, p 207).

Evidently this electronic transfer within the chromosome of the infected host cannot completely explain the formation of the phage, because the synthesis of the proteinic "fritter" in which the DNA of the phage takes refuge occurs

simultaneously. But a theoretic study explains the fact that there is no multiplication of the phage through division of the DNA phage, but rather synthesis of the DNA phage on the basis of the components of the prophage and of part of the components of the DNA of the infected bacterium.

A theoretic study also allows us to understand why, in the absence of one of the DNA or RNA nucleic acids, a living organism cannot reproduce. In order to multiply, it has to infect a host that provides it either (a) with the nucleic acid that it does not have, or (b) with the same nucleic acid modified on one of its peaks, therefore with a different electronic structure, so that one may be a "donor" and the other an "acceptor".

It seems that to initiate every cellular multiplication there is an intra-nucleic acid electronic transfer.

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